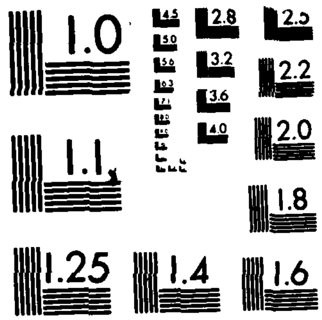
AD-A142 245 GLASSES FOR FIBER-OPTIC SENSORS(U) NATIONAL BUREAU OF STANDARDS WASHINGTON DC D H BLACKBURN ET AL. OCT 82 N00173-82-F-D044 1/1

UNCLASSIFIED F/G 11/2 NL

END
DATE
FILMED
7-84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A142 245

Technical Report

GLASSES FOR FIBER-OPTIC SENSORS

D. H. Blackburn, A. Feldman, and R. M. Waxler

October 1982

Prepared for the Naval Research Laboratory

Monitor: N. Lagakos
Principal Investigator: A. Feldman

Period Covered: October 1, 1981-September 30, 1982

N00173-82-F-D044

GLASSES FOR FIBER-OPTIC SENSORS

1. Objective

To measure the relevant optical and mechanical properties of commercial glasses and glasses prepared at the National Bureau of Standards for the purpose of determining their suitability as fiber-optic sensor materials.

2. Introduction

The Department of the Navy is interested in the development of fiber-optic sensors for the detection of underwater acoustic waves. An advantage of such sensors over conventional piezoelectric sensors is their insensitivity to electromagnetic interference. However, a source of noise in such sensor systems is expected to arise from optic path variations due to temperature and pressure fluctuations in the fiber-optic leads connected to the sensors. In order to minimize this noise, a program has been instituted at the Naval Research Laboratory to develop fibers that are insensitive to pressure and temperature fluctuations. In order to assist with this program, the Glass Group of the National Bureau of Standards has been preparing experimental glasses and measuring their relevant mechanical and optical properties.

The work this year has centered on the development of cladding glasses for pressure insensitive fibers. The accomplishments have been: (a) the synthesis of eight glasses of varying composition for the minimization of linear thermal expansion coefficient; (b) the measurement of elastic moduli and thermal expansion coefficients of the aforementioned glasses; (c) the development of glasses with linear thermal expansion coefficients comparable to Pyrex; (d) the fabrication of a cladding preform from one of the NBS produced glasses which was selected for optimum values of bulk modulus and linear thermal expansion coefficient so as to produce a pressure insensitive fiber; (e) the provision of bulk specimens and thin rods to EOTEK Corporation

per instructions from the contract monitor; and (f) the filing of an invention disclosure with the NBS patent attorney to ascertain whether the glass compositions formulated at NBS merit a patent. to p. 1

3. Results

It has been pointed out that substrate materials for pressure insensitive fiber-optic leads should have a large bulk modulus and a small thermal expansion coefficient. To this end, NBS has been preparing a series of experimental glasses. In the previous year, in a series of eleven glasses, we had shown that the gradual addition of Ta_2O_5 and removal of CaO from a calcium aluminate based glass formulation led to glasses with both a large bulk modulus and a decreasing linear thermal expansion coefficient. For the present year, eight additional experimental glasses were synthesized with the hope of further decreasing the thermal expansion coefficient without adversely affecting the bulk modulus.

The method of specimen preparation and the measurement of elastic moduli and thermal expansion were presented in our previous report and so will not be discussed here. Table 1 summarizes the results of this year's study and the study of the previous year. The eight glasses studied this year are denoted by K-1780 and higher. It was found that as the concentration of Ta_2O_5 was increased, the linear thermal expansion coefficient reached a minimum value and then began to increase. Two glasses, K-1824 and K-1825, had Nb_2O_5 substituted for Ta_2O_5; no significant change was found in the bulk modulus, but the linear thermal expansion appeared to increase slightly. Some B_2O_3 was added to glasses K-1847 and K-1848 as small amounts of this substance are known to decrease expansion coefficients. Indeed, K-1848 had the smallest expansion coefficient in the series. However, the bulk modulus showed a significant decrease.

Based on the results for the nineteen glasses, it was decided that glass K-1780 had the best combination of properties for the production of a cladding preform. This glass has a respectfully large bulk modulus and a linear thermal expansion coefficient comparable to Pyrex. A cladding preform of this glass was fabricated at NBS and shipped to EOTEK Corporation which is under contract with NRL for prototype drawing of fibers. EOTEK also required bulk material and some thin rods so as to study the fiber drawing properties of the NBS glass prior to the use of the preform; these specimens were prepared and have been sent to EOTEK.

The glasses we have formulated have some unique properties which make them useful for a variety of applications. We have, therefore, prepared an invention disclosure for the NBS patent attorney to evaluate. A copy of this disclosure is attached; it outlines some of the more important applications for these glasses.

References

1. N. Lagakos and J. A. Bucaro, "Pressure Desensitization of Optical Fibers," Appl. Opt., 20, 2716 (1981).

Table 1.

Properties of NBS Prepared Glasses

Glass No.	CaO	Al_2O_3	MgO	TiO_2	ZrO_2	SiO_2	Ta_2O_5	Nb_2O_5	B_2O_3	Young's Modulus	Shear Modulus	Bulk Modulus	Poisson's Ratio	$\alpha(10^{-6}/K)$ at 20 °C
	weight %									(10^{11} dyn/cm^2)				
K-1671	25	25	10	10	10	20				11.62	4.52	9.01	0.285	6.49
K-1679	25	20	10	10	10	25				11.45	4.45	8.92	0.286	6.21
K-1689	30	15	10	10	10	25				11.31	4.40	8.81	0.286	7.21
K-1701	25	20	10	10		25	10			11.20	4.37	8.52	0.281	6.75
K-1703	20	20	10	10		25	15			11.46	4.46	8.88	0.285	5.95
K-1717	20	20	15	10		25	10			11.55	4.50	8.87	0.283	6.48
K-1719	20	20	10	15		25	10			11.48	4.49	8.66	0.279	6.07
K-1729	15	20	10	10		25	20			11.65	4.54	8.99	0.284	5.62
K-1733	10	20	10	10		25	25			11.62	4.56	8.65	0.276	4.85
K-1734	5	20	10	10		25	30			11.90	4.65	9.06	0.281	4.35
K-1772	0	20	10	10		30	30			11.56	4.63	7.71	0.250	3.21
K-1780		20	20	5		35	30			11.31	4.42	8.52	0.279	2.94
K-1787		20	10			35	35			11.04	4.39	7.54	0.256	2.88
K-1788		20	10			30	40			11.52	4.57	8.07	0.262	2.94
K-1789		20	10			25	45			12.14	4.78	8.82	0.271	3.13
K-1824		20	10			30	20	20		11.36	4.48	8.12	0.268	3.02
K-1825		20	10			30		40		11.30	4.45	8.14	0.268	3.22
K-1847		20	10			26.25	35		8.75	10.52	4.22	6.88	0.245	2.84
K-1848		20	10			30	35		5.0	10.78	4.26	7.63	0.263	2.69

PATENT DISCLOSURE

Low Compressibility, Low Expansivity Glasses

Douglas Blackburn, Albert Feldman
Glass and Optical Materials Group
National Bureau of Standards

and

Nicolas Lagakos
Physical Acoustics Branch
Naval Research Laboratory

A series of beryllium-free glasses have been formulated that exhibit a high Young's modulus (E), a high bulk modulus (K), and a wide range of expansivities. Several of the glasses exhibit unusually small linear thermal expansion coefficients (α) at room temperature. The glasses were formulated with the view of not including BeO as a constituent because of its potential toxicity.

<u>Formulations:</u>

The compositions fall in the following weight percent ranges:

CaO_2	0 - 30%
Al_2O_3	15 - 25%
MgO	5 - 15%
TiO_2	0 - 15%
ZrO_2	0 - 10%
SiO_2	20 - 30%
B_2O_3	0 - 10%
Ta_2O_5	0 - 45%
Nb_2O_5	0 - 40%

Particular compositions show desirable combinations of properties. The highest Young's modulus was exhibited by the glass with the following composition:

Al_2O_3	20%	$E = 12.1 \times 10^{11}$ dyn/cm^2
MgO	10%	$K = 8.8 \times 10^{11}$ dyn/cm^2
SiO_2	25%	$\alpha = 3.1 \times 10^{-6}$/°C at 20 °C
Ta_2O_5	45%	

The highest bulk modulus was exhibited by the glass with the following composition:

CaO	5%	
Al_2O_3	20%	$E = 11.9 \times 10^{11}$ dyn/cm^2
MgO	10%	$K = 9.1 \times 10^{11}$ dyn/cm^2
Ti_2O_3	10%	$\alpha = 4.4 \times 10^{-6}$/°C at 20 °C
SiO_2	25%	
Ta_2O_5	30%	

The smallest linear thermal expansion coefficient was exhibited by the glass with the following composition:

Al_2O_3	20%	
MgO	10%	$E = 10.8 \times 10^{11}$ dyn/cm^2
SiO_2	30%	$K = 7.6 \times 10^{11}$ dyn/cm^2
Ta_2O_5	35%	$\alpha = 2.7 \times 10^{-6}$/°C at 20 °C
B_2O_3	5%	

The following glass composition was optimized to possess a large bulk modulus and a small linear thermal expansion coefficient:

Al_2O_3	20%	
MgO	10%	$E = 11.3 \times 10^{11}$ dyn/cm^2
TiO_2	5%	$K = 8.5 \times 10^{11}$ dyn/cm^2
SiO_2	35%	$\alpha = 2.9 \times 10^{-6}$ /°C at 20 °C
Ta_2O_5	30%	

Uses:

(1) Glasses for graded seals. Thermal expansion coefficients at 20 °C in the range 2.7×10^{-6} to 7.2×10^{-6} are obtainable.

(2) Temperature stable optical glass. Because the melts of the glasses described herein are of low viscosity, it is possible to produce homogeneous glasses possessing low expansivities. The expansivity of the glass with the smallest expansion coefficient approximates the expansivity of Pyrex. However, because of its high melt viscosity, Pyrex is not usable as a high quality optical glass.

(3) Pressure insensitive fibers. Cladding glasses with high bulk modulus are required to produce fibers that are insensitive to pressure fluctuations. Typically, fiber cores are made from high silica glasses, which have very small expansivities; thus, in order to produce mechanically stable fibers, with these core glasses, it is necessary to use cladding glass with small expansivities. The glasses described herein can be produced both with high bulk modulus and low expansivity thus increasing the probability for successful drawing of pressure insensitive fibers.

Importance of Pressure Insensitive Fibers

A major research effort is underway, especially at the Department of Defense, for development of fiber-optic sensors as an alternate technology to current sensor technology. Such sensors would be used for sensitive detection of pressure, temperature, electric fields and magnetic fields. These sensors require special fiber-optic cables for transmission and reception of sensor signals over distances of several kilometers. Over such large distances, fluctuations in the ambient pressure will lead to superimposition of noise on the sensor signal. Thus fiber-optic cables insensitive to these pressure fluctuation are required for maximizing the signal to noise ratio in the received signals. Immediate potential applications for these fibers would be underwater acoustic detection, acoustic detection related to oil exploration, acoustic detection related to underground nuclear explosions, and earthquake detection.

FORM CD-240
(REV. 6-69)
PRES. BY
DAO 206-2-5-A

U.S. DEPARTMENT OF COMMERCE

FOR PATENT ADVISER'S USE

Case No.

INVENTION DISCLOSURE AND RIGHTS QUESTIONNAIRE

INSTRUCTIONS: Complete and send to Patent Adviser, Office of the Legal Adviser, National Bureau of Standards, Washington, D.C. 20234.

Title of Invention *(Attach full description)*

Low Compressibility, Low Expansivity Glasses

Inventor	Title and Grade		
Douglas Blackburn	Chemist, GS-13		
Division Name	**Building**	**Room No.**	**Telephone**
Materials Chemistry Division	Matls/223	B316	x.2817
Inventor	**Title and Grade**		
Albert Feldman	Physicist, GS-15		
Division Name	**Building Room No.**	**Room No.**	**Telephone**
Materials Chemistry Division	Matls/223	A249	x.2817
Inventor	**Title and Grade**		
Nicolas Lagakos	Physicist, GS-13		
Division Name	**Building**	**Room No.**	**Telephone**
Naval Research Laboratory	71	Code 5134	767-3179

STATEMENT OF INVENTOR(S)

	Yes	No
1. Has the invention been published? *(Attach copy of paper, preprint, report, etc.)* Informal report attached		X
2. Has the invention been used only experimentally?	X	
3. Do you know of relevant prior art? *(Attach copy)* NBS Report No. 5188 (1957)	X	
4. Was the invention sponsored by another agency? *(Identify agency and Order No.)* Naval Research Lab. N00173-82-F-D044	X	
5. Does the invention bear a direct relation to or was it made in consequence of your official duties? *(If no, attach copy of position description)*	X	
6. Was the invention made		
A. *During working hours*	X	
B. With a contribution by the government of		
a. Facilities	X	
b. Equipment	X	
c. Materials	X	
d. Funds	X	
e. Information available only by reason of your official duties	X	
f. Time or services of other government employees on official duty	X	

7. Estimate the market for the invention.

Selling price $ ______ x Number of sales ______ = Market $ 10M-100M at least

8. CERTIFICATION OF INVENTOR(S)

Signature	Date
Douglas Blackburn *Douglas Blackburn*	9-20-82
Albert Feldman *Albert Feldman*	9-17-82
Nicolas Lagakos *Nikolas Lagakos per af.*	9-20-82

SUPERVISORY CONCURRENCE

	Yes	No
9. Do you agree with the replies to questions 1 — 7?		
10. Are you aware of any question as to inventorship?		

Signature of Supervisor	Date	Signature of Division Chief	Date
		TDCoyle	9/21/82

USCOMM-DC 89-6030

DATE

FILMED